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14. ABSTRACT

This grant was concerned with the development of the linear sampling method to determine the location and shape of hostile structures hidden in a known background medium from measured electromagnetic scattering data. The research included the numerical investigation of the ultra-weak variational formulation for Maxwell's equations and the solution of the inverse scattering problem for partially coated obstacles. Since it has previously been shown that the scattering due to the background can be subtracted off in a rigorous manner, for theoretical purposes it suffices to consider these problems for obstacles in a homogeneous background medium.

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Objectives

This grant is concerned with the development of the linear sampling method to determine the location and shape of hostile structures hidden in a known background medium from measured electromagnetic scattering data. The proposed research includes the numerical investigation of the ultra-weak variational formulation for Maxwell's equations and the solution of the inverse scattering problem for partially coated obstacles. Since it has previously been shown that the scattering due to the background can be subtracted off in a rigorous manner, for theoretical purposes it suffices to consider these problems for obstacles in a homogeneous background medium.

Status of Effort

The major objective of this proposal was to derive the linear sampling method for Maxwell's equations and to demonstrate its utility in the detection of partially coated objects. In particular, in order to avoid detection, hostile structures are typically partially coated with complex dielectric materials whereas decoys such as wooden "missiles" or "tanks" are partially coated by a thin metallic sheet in order to appear hostile. The presence of such a coating and the fact that its material properties are unknown, makes the problem of target identification particularly difficult using traditional inverse scattering techniques. However, the linear sampling method [14] is particularly well suited to such applications and hence was the method of choice for achieving the goals of this proposal.

We began by considering the inverse scattering problem for perfect conductors and imperfectly conducting obstacles and gave numerical examples of the viability of the linear sampling method in these cases [13]. We then proceeded to show how the linear sampling method can also be used to determine the support of an isotropic inhomogeneous medium from a knowledge of the far field pattern of the scattered electromagnetic wave [16]. The important practical case of limited aperature far field data was considered in [1]. Having examined the above "classical" inverse scattering problems for Maxwell's equations, we then turned our attention to target identification problems for partially coated objects. We first considered the case of a perfect conductor that is partially coated by a thin dielectric layer and showed how both the shape and the surface impedance of the layer can be determined from far field data [7], [9]. Here the basic mathematical difficulty is to successfully treat mixed boundary value problems in inverse electromagnetic scattering theory where it is not known a priori whether or not the unknown object is partially coated and, if so, what are the material properties and extent of the coating. Finally, in [3] and [11], we turned our attention to the inverse scattering problem for a dielectric that is partially coated by a thin layer of a highly conducting material and showed how both the shape and surface conductivity can be determined from the far field data.

For testing the inversion algorithms mentioned above we needed to compute far field data from complex scatterers (i.e. multiply connected with coatings). We therefore needed a high order and flexible solver for the time-harmonic Maxwell system. We have investigated finite element methods for some time and the results of this investigation have appeared in a book [20]. However, for testing the above inversion procedures we have relied on the ultra weak variational formulation of Maxwell's equations using a plane wave basis on a sharply graded finite element grid. This method has good dispersion properties, and is easier to compute than the finite element method, but can suffer from conditioning limitations and is not fully understood theoretically. In [15] we have shown that the method converges, for a fixed grid, as the number of plane waves per element is increased.

Accomplishments/New Findings

The main accomplishments during the period of this report were 1) the successful use of the linear sampling method to determine the support of an isotropic inhomogeneous medium and the shape of a (possibly) partially coated perfect conductor or dielectric and 2) the derivation of an explicit formula giving the surface impedance of a partially coated perfect conductor from a knowledge of the far field pattern of the scattered electromagnetic wave and an analogous formula giving a lower bound for the surface conductivity of a partially coated dielectric.

Personnel Supported

1. Faculty
   D. Colton and P. Monk (Principal Investigators)

2. Graduate Student
   W. Muniz (supported by the University of Delaware)

3. Post Doctoral student
   E. Darrigrand (supported by the University of Delaware)

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Interactions/Transitions

Professors Colton and Monk have attended numerous conferences and seminars as invited speakers both in this country and in Europe.